INDOOR AIR QUALITY ASSESSMENT

Chapin Elementary School
40 Meadow Street
Chicopee, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality Program
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Background/Introduction

At the request of Ronald Simard of the Chicopee School Department, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) was asked to provide assistance and consultation regarding indoor air quality concerns at the Chapin Elementary School (CES), 40 Meadow Street, Chicopee, MA. Mike Feeney, Director of BEHA's Emergency Response/Indoor Air Quality (ER/IAQ) program visited the CES on April 1, 2003. Mr. Feeney was accompanied by Mr. Simard, as well as Judy Dean, American Lung Association, during the assessment. Reports of inadequate ventilation, odors, lack of temperature control and other indoor air quality issues prompted the assessment.

The school is a two-story, red brick building, built in 1900. An addition was constructed in the 1930s. The CES has a full attic. The second floor contains general classrooms. The first floor contains the main office, cafeteria, nurse's office, several classrooms and several specialty rooms. Located on the basement level are the kitchen, several other specialty classrooms, boiler room and the storerooms.

Methods

Air tests for carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor, Model 8551.

Results

The CES currently houses students in grades K-3. It has a student population of approximately 198 and a staff of approximately 40. Tests were taken under normal operating conditions. Test results appear in Table 1.

Discussion

It can be seen from the tables that carbon dioxide levels were elevated above 800 ppm (parts per million) in eleven out of nineteen occupied areas surveyed, which indicates inadequate airflow in a number of areas of the school. Please note that three classrooms with carbon dioxide levels below 800 ppm were not occupied during air testing. Carbon dioxide levels would be expected to rise with occupancy.

The building does not have a modern mechanical ventilation system, but originally used a gravity/natural ventilation system to provide airflow to most classrooms in combination with openable windows. Ventilation is provided by a series of louvered vents. Each classroom has an approximately 3' x 3' grated air vent on an interior wall near the ceiling (see Picture 1), which is connected by an airshaft to a chamber in the basement (the air mixing chamber). Inside each chamber is a heating element that was connected to the school boiler. These vents were originally designed with pull-chains connected to louvers, which adjust the airflow. A corresponding 3' x 3' vent exists in each room near the classroom doorways, which is connected to an exhaust ventilation shaft that runs from the roof to the basement. Four of these exhaust ventilation shafts open into the air-mixing chamber. Classrooms were constructed around these shafts to provide exhaust ventilation. Each of the ventilation shafts extends through the roof (see Picture 2) on either side of the school and terminate in a "hearth"-like opening in the air-mixing chamber (see Picture 3).

Air movement is provided by the stack effect. Located in the air-mixing chamber is a large heating element (see Picture 4). Heating elements were also installed in airshafts above classroom exhaust vents. The heating elements warm the air, which rises up the ventilation shafts. As the heated air rises, negative pressure is created, which draws cold air from the basement area into the heating elements. This system is designed to draw air from two sources in the basement: fresh air from an openable window on the exterior wall of the building and return air from the exhaust ventilation shafts. Outside and return air is mixed in the air mixing chambers prior to being drawn into the heating elements. The percentage of fresh air to return air is controlled by a window in the air mixing room. Fresh air in winter is supplied throughout the building by the warm air vents.

Exhaust ventilation is provided by cool air vents. As the heating elements draw air into the warm air ducts, return air is drawn from the "hearths" at the bottom of the exhaust ventilation shafts. Negative pressure is created in these shafts, which in turn draws air into the cool air vents of each classroom. The draw of air into these cool air vents is controlled by a draw chain pulley system. A percentage of return air rises up the ventilation shaft to exhaust outdoors.

Different portions of the gravity ventilation system have been abandoned. Exhaust vents were sealed with plywood (see Picture 5). Heating elements in the air mixing rooms and within exhaust vents have also been disconnected. Lastly, the windows in the air mixing chambers were replaced with non-openable windows. The result of this abandonment disabled the ability of the gravity ventilation system to distribute fresh air into the CES. Currently, the sole source of fresh air in classrooms is the window system.

During summer months, ventilation is controlled by the use of openable windows in classrooms. The CES was configured in a manner to use cross-ventilation to provide comfort for building occupants. The building is equipped with windows on opposing exterior walls. In addition, the building has hinged windows located above the hallway doors. This hinged window (called a transom) (see Picture 6) enables the classroom occupant to close the hallway door while maintaining a pathway for airflow. This design allows for airflow to enter an open window, pass through a classroom, pass through the open transom, enter the hallway, pass through the opposing open classroom transom, into the opposing classroom and exit the building on the leeward side (opposite the windward side) (see Figure 1). With all windows and transoms open, airflow can be maintained in a building regardless of the direction of the wind. The system fails if the windows or transoms are closed (see Figure 2). A long pole with a hook was typically used to open the hoop latch that locks the transom closed in each classroom. Most transoms in the building were closed during the assessment, which can inhibit airflow in the summer.

Occupied spaces in the basement do not appear to have direct sources of ventilation. The adjustment counselor's office is not equipped with mechanical ventilation, but has passive vents installed in the doors designed to draw air from the hallway. Without proper supply and/or exhaust ventilation, indoor air pollutants can build up and lead to indoor air quality/comfort complaints. Some basement areas have no means of mechanical ventilation or openable windows.

In order to have proper ventilation with a mechanical supply and exhaust system, these systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). Please note that the ventilation systems, in their condition at the time of the assessment, cannot be balanced.

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied.

Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week based on a time weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see Appendix I.

Temperature readings were measured in a range of 67° F to 77 ° F, which were within the BEHA comfort guidelines for all areas, save one classroom (see Table). The BEHA recommends that indoor air temperatures be maintained in a range of 70 ° F to 78 ° F in order to provide for the comfort of building occupants. A number of temperature control/comfort complaints were expressed by occupants throughout the building. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. It is often difficult to control temperature and maintain comfort without operating the ventilation equipment as designed (i.e. the building's original ventilation system has been abandoned).

The relative humidity in the building ranged from 18 to 30 percent, which was below the BEHA recommended comfort range. The BEHA recommends that indoor air relative humidity is comfortable in a range of 40 to 60 percent. The sensation of dryness and irritation is common in a low relative humidity environment. Relative humidity levels in the building would be expected to drop during the winter months due to heating.

Microbial/Moisture Concerns

Potential sources of microbial growth and associated odors were also observed. Musty, mold-like odors were detected in the teacher's room. The teacher's room has wall paneling installed along exterior foundation walls (see Picture 7). In general, wall paneling installed in this manner may conceal and contain moisture from water penetration through the foundation wall through the exterior wall/tarmac junction or condensation on the cement. In either case, the paneling can serve to prevent the evaporation of moisture and can result in repeated moistening of wall paneling and wall-to-wall carpeting. Wall materials, such as paneling, can serve as a mold growth medium.

In addition, signs or water penetration through foundation walls were evidenced by the presence of peeling paint and efflorescence along exterior walls in areas with exposed, painted foundation wall brick (see Picture 8). Efflorescence is a characteristic sign of water damage to brick and mortar, but it is not mold growth. As moisture penetrates and works its way through mortar around brick, water-soluble compounds in bricks and mortar dissolve, creating a solution. As the solution moves to the surface of the brick or mortar, the water evaporates, leaving behind white, powdery mineral deposits. A coat of paint can serve as a water impermeable barrier, which can collect moisture and efflorescence. Brick, mortar and wall plaster are not good mold growth media, however water trapped behind paint can serve that purpose.

Different means for water to have prolonged contact with the foundation wall exist around the perimeter of the building. Small trees and other plants were seen growing in the tarmac/exterior wall junctions. In addition, downspouts for the building empty near the foundation (see Picture 9). The growth of roots against the exterior of foundation walls, as well as spaces between the tarmac, can bring moisture in contact with brick and foundation structures, which may eventually lead to moisture penetration below ground level areas of the building. Over time, this process can undermine the integrity of the building envelope and provide a means of water entry into the building via capillary action through foundation concrete and masonry (Lstiburek & Brennan, 2001).

Several classrooms contained a number of plants. Plant soil and drip pans can serve as a source of mold growth. Plants and potting soil were found on top of univents in several classrooms. Some plants were noted in standing water. Plants should be properly maintained and be equipped with drip pans.

Other Concerns

Several other conditions were noted during the assessment, which can affect indoor air quality. Of note was the existence of a large pipe that served as a coal chute in one of the air mixing rooms in the basement (see Picture 10). A number of holes were seen in the chute, which can allow air to move from the chute interior into the air mixing room. The coal chute appears to enter the boiler room. As previously noted, the original fresh air supply vents in some classrooms are connected by airshafts to openings above the heating elements in this room. Under certain circumstances, odors and particulates from the boiler room can use the coal chute as a pathway to migrate into the air mixing room, which can travel into classrooms via the abandoned fresh air supply shafts. Several former pipe penetrations through a boiler room wall appear to penetrate into the air mixing room in the center of the building as well (see Picture 11). Other pathways exist for indoor pollutants to migrate from one area to another. Utility holes in basement interior walls (see Pictures 12 and 13) were observed. All of these breaches can serves as pathways for odors, drafts and particulates to migrate between rooms and floors.

A number of classrooms contained upholstered furniture. Upholstered furniture is covered with fabric that comes in contact with human skin. This type of contact can leave oils, perspiration, hair and skin cells. Dust mites feed upon human skin cells and excrete waste products that contain allergens. In addition, if relative humidity levels increase above 60 percent, dust mites tend to proliferate (US EPA, 1992). In order to remove dust mites and other pollutants, frequent vacuuming of upholstered furniture is recommended (Berry, 1994). It is also recommended that upholstered furniture (if present in schools), be professionally cleaned on an annual basis. If an excessively dusty environment exists due to outdoor conditions or indoor activities (e.g. renovations), cleaning frequency should be increased (every six months) (IICR, 2000). Elevated outdoor levels of airborne particulates can result in increased levels of indoor particulates by entering into the building through open windows, doors and filter bypass.

While in the attic, bat wastes were also observed (see Picture 14). Bats in a building raise concerns over diseases that may be caused by exposure to bat wastes. These conditions warrant clean up of bat waste and appropriate disinfection. Certain molds (*Histoplasma capsulatum)* are associated with bat waste (CDC, 2001; NIOSH, 1997) and are of concern for immune compromised individuals. Diseases of the respiratory tract may also result from exposure to bat waste. While immune compromised individuals have an increased risk of health impacts following exposure to the materials in bat wastes, these impacts may also occur in healthy individuals exposed to these materials.

The methods to be employed in clean up of a bat waste problem depends on the amount of waste and the types of materials contaminated. The MDPH has been involved in several indoor air investigations where animal waste has accumulated within ventilation ductwork. Accumulation of bat wastes have required clean up of such buildings by a professional cleaning contractor. In less severe cases, the cleaning of the contaminated material with a solution of sodium hypochlorite has been an effective disinfectant (CDC, 1998). Disinfection of non-porous materials can be readily accomplished with this material. Porous materials contaminated with bat waste should be examined by a professional restoration contractor to determine if the material is salvageable. Where a porous material has been colonized with mold, it is recommended that the material be discarded (ACGIH, 1989).

A number of classrooms contained dry erase boards. Dry erase board particulates can be easily aerosolized and serve as eye and respiratory irritants. In addition, materials such as dry erase markers and dry erase board cleaners may contain VOCs (e.g., methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve) (Sanford, 1999), which can also be irritating to the eyes, nose and throat.

Finally, it is also worthy to note the amount of materials stored inside classrooms. In classrooms throughout the school, items were observed on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provide a source for dusts to accumulate. These items (e.g. papers, folders, boxes) also make it difficult for custodial staff to clean. Dust can be irritating to eyes, nose and respiratory tract. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up.

Conclusions/Recommendations

The conditions noted at the CES raise a number of indoor air quality issues. The combination of the general building conditions, maintenance, design and the operation (or lack) of HVAC equipment, if considered individually, present conditions that could degrade indoor air quality. When combined, these conditions can serve to further negatively affect indoor air quality. Some of these conditions can be remedied by actions of building occupants. Other remediation efforts will require alteration to the building structure and equipment. For these reasons a two-phase approach is required, consisting of **short-term** measures to improve air quality and **long-term** measures that will require planning and resources to adequately address overall indoor air quality concerns.

The following **short-term** measures should be considered for implementation:

1) Use open windows and hallway doors to enhance airflow during warm weather. Be sure to close windows and doors at the end of the school day. To aid in the draw of fresh outdoor air in warm weather, use portable fans directing air out windows on the leeward side of the building. Fans positioned in this manner will serve to increase the draw of outdoor air across a floor without interfering with the natural, internal airflow pattern of the building. To aid cross ventilation, open hallway doors in areas with inoperable transoms.

2) If original mechanical ventilation systems are not fully restored, ensure abandoned exhaust and supply vents are properly sealed in classrooms, the basement and on the roof to eliminate pathways for movement of odors and particulates into occupied areas.

3) Seal the holes in the coal chute.

4) Seal all openings in former air handling rooms.

5) Seal all holes and abandoned pipes in the walls of the boiler room.

6) Remove and replace any mold contaminated/water damaged wall paneling, insulation, carpeting and ceiling tiles in the teacher's room. This measure will remove actively growing mold colonies that may be present. Remove mold contaminated materials in a manner consistent with recommendations found in "Mold Remediation in Schools and Commercial Buildings" published by the US Environmental Protection Agency, Office of Air and Radiation, Indoor Environments Division, Washington, DC. EPA 402-K-01-001. March 2001. Copies of this document can be downloaded from the US EPA website at: http://www.epa.gov/iaq/molds/mold_remediation.html

7) To prevent moisture penetration into the basement, the following actions should be considered:

   a) Remove foliage to no less than five feet from the foundation.

   b) Improve the grading of the ground away from the foundation at a rate of 6 inches per every 10 feet (Lstiburek, J. & Brennan, T.; 2001).

   c) Install a water impermeable layer on ground surface (clay cap) to prevent water saturation of ground near foundation (Lstiburek & Brennan, 2001).

8) Seal the exterior wall/tarmac seal to prevent water penetration.

9) For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

10) Move plants away from univents in classrooms. Avoid over-watering and examine drip pans periodically for mold growth. Disinfect with an appropriate antimicrobial where necessary.

11) Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.

12) Clean dry erase board trays regularly to avoid the build-up of particulates.

13) Remove bats from attic/roof structures. Install a roof cap on chimney to prevent bat entry.

The following **long-term measures** should be considered:

1. Based on the age, physical deterioration and availability of parts for ventilation components, the BEHA strongly recommends that an HVAC engineering firm fully evaluate the ventilation system.

2. Examine the feasibility of providing mechanical supply and exhaust ventilation. Determine if existing airshafts, vents, ductwork, etc. can be retrofitted for (modern) mechanical ventilation.

3. Thermostat settings throughout the school should be evaluated. Thermostats should be set at temperatures to maintain comfort for building occupants.

4. In order to maintain a good indoor air quality environment in the building, consideration should be give to adopting the US EPA document, “Tools for Schools”, which can be downloaded from the Internet at http://www.epa.gov/iaq/schools/index.html.
5. For further building-wide evaluations and advice on maintaining public buildings, see the resource manual and other related indoor air quality documents located on the MDPH’s website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

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Figure 1 **Cross Ventilation in a Building Using Open Windows and Transoms**

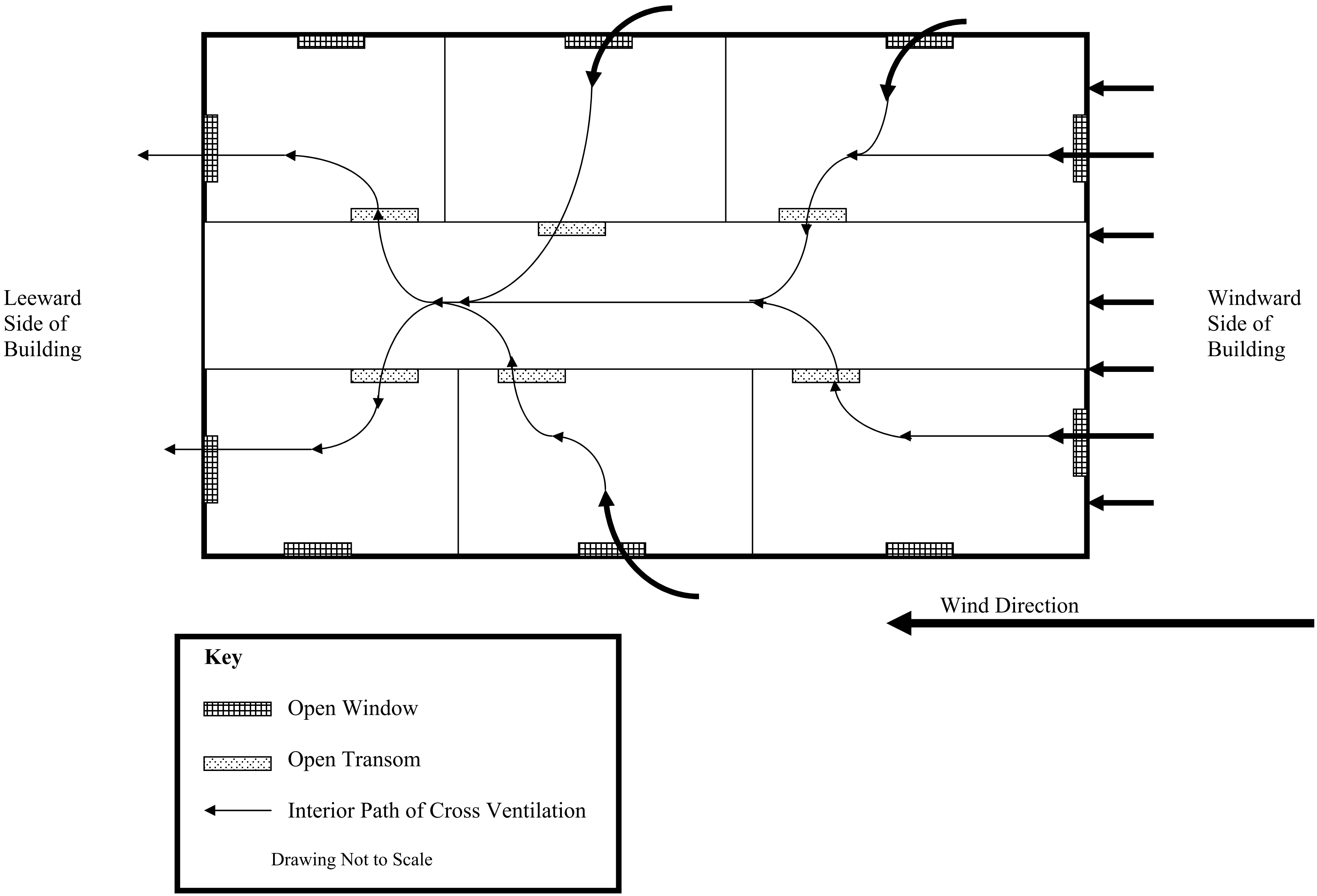
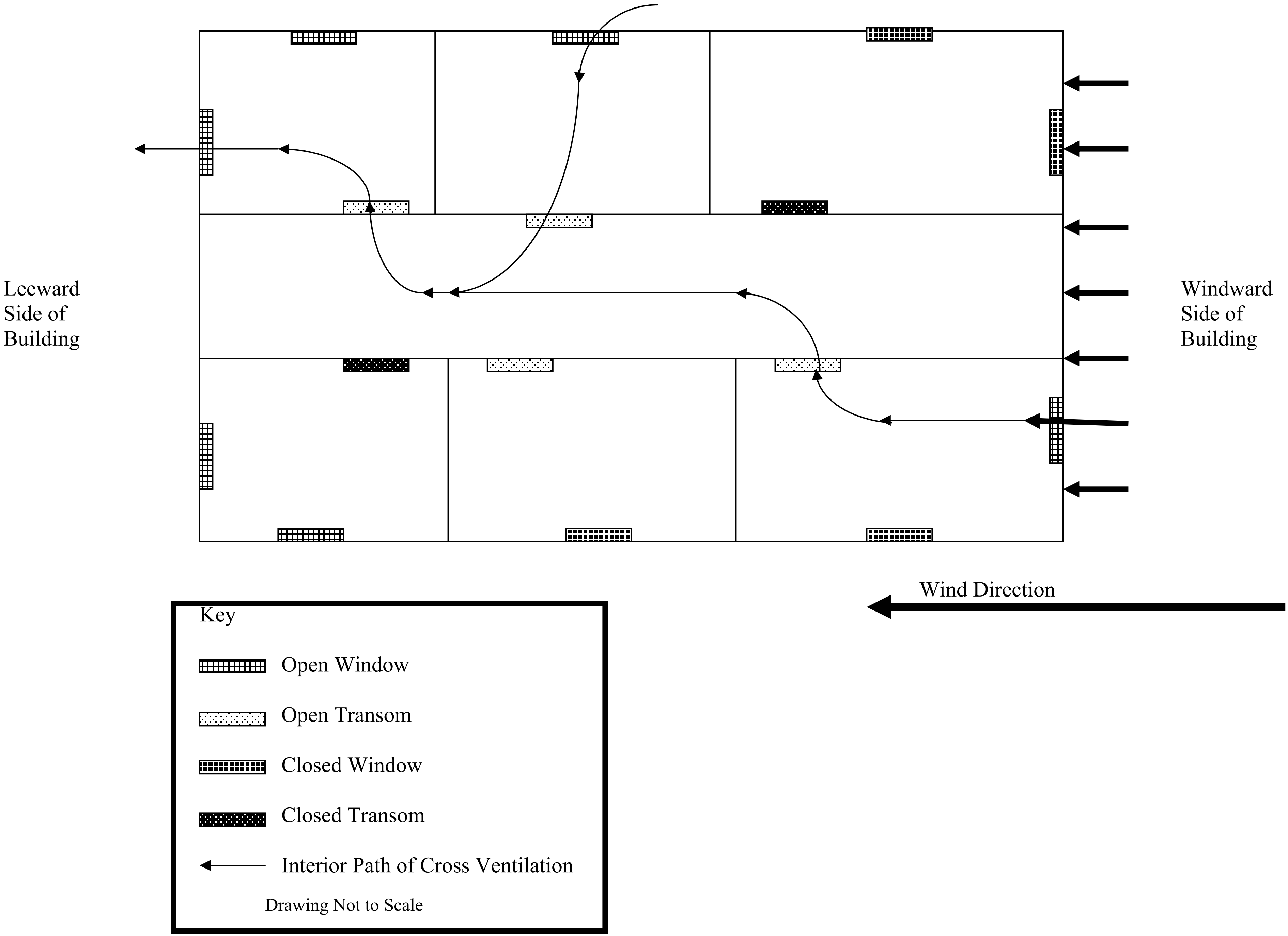
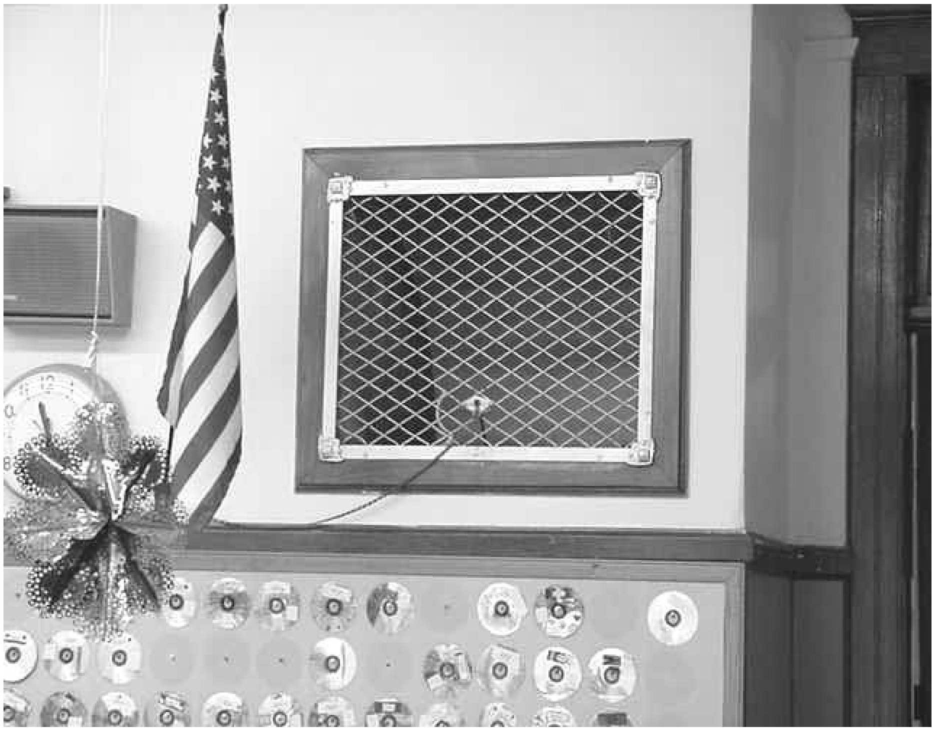


Figure 2 **Inhibition of Cross Ventilation in a Building with Several Windows and Transoms Closed**



Picture 1

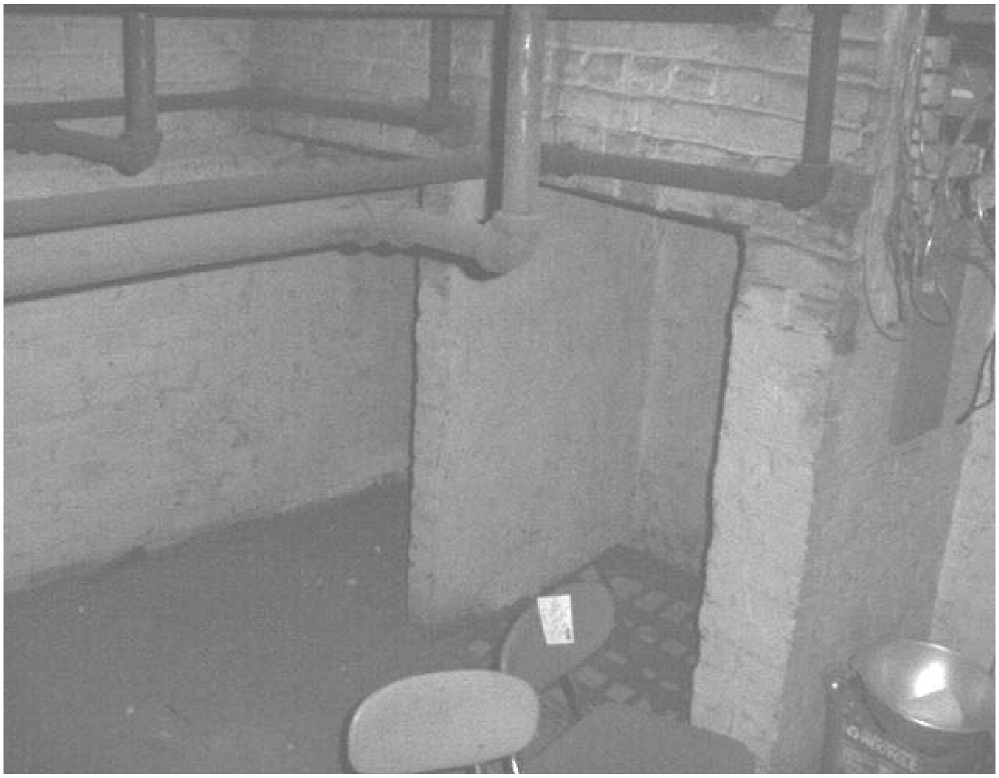


Grated Fresh Air Vent

Picture 2

Rooftop Air Shaft Termini

Picture 3



“Hearth”-Like Opening in the Air-Mixing Chamber

Picture 4

Heating Element in Air Mixing Room

Picture 5

Exhaust Vent Sealed with Plywood

Picture 6

Transom

Picture 7

Wall Paneling in Teacher's Room in Basement

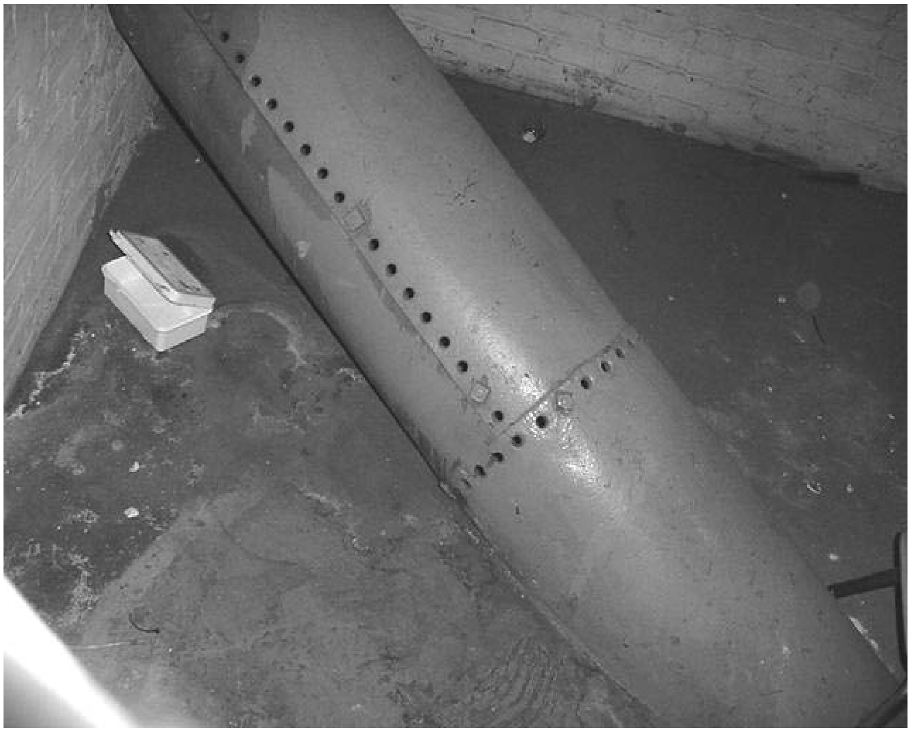
Picture 8

Peeling Paint in Below Grade Classroom

Picture 9

Downspout Outside Of Classroom with Peeling Paint in Picture 9

Picture 10



The Coal Chute, Note Holes

Picture 11

Holes/Abandoned Pipes in Boiler Room Wall

Picture 12

Hole in Basement Interior Wall

Picture 13

Hole in Basement Interior Wall

Picture 14

Bat Waste in Attic

TABLE 1

Indoor Air Test Results –Chapin Elementary School, Chicopee MA April 1, 2003

Location	Carbon Dioxide *ppm	Carbon Monoxide	Temp °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
							Supply	Exhaust	
Outdoors (Background)	384	0	43	31					
Art Room 16	582	0	32	32	0	Y	N	N	
Room 9	1002	0	67	30	10	Y	Y	N	Door open 20 computers
Library 16	751	0	71	23	1	Y	Y	N	WB Hole – cement
Room 15	675	0	72	20	0	Y	Y	N	WB Door open
Room 14	785	0	71	18	20	Y	Y	N	Door open
Room 13	567	0	72	21	0	Y	Y	N	Plants
Room 12	966	0	74	20	22	Y	Y	N	Door open
Room 11	1142	0	72	22	0	Y	Y	N	WB
Room 10	1040	0	71	25	0	Y	Y	N	
Room 2	1112	0	74	25	22	Y	Y	N	Door open Clutter

*** ppm = parts per million parts of air**
WB = wall erase board

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 1

Indoor Air Test Results –Chapin Elementary School, Chicopee MA **April 1, 2003**

Location	Carbon Dioxide *ppm	Carbon Monoxide	Temp °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
							Supply	Exhaust	
Room 1	982	0	74	22	22	Y	Y	N	Clutter
Room 8	964	0	74	22	25	Y	Y	N	Door open
Cafeteria	1014	0	75	22	50+	Y	Y	N	Refrigerators
Room 6	892	0	77	20	1	Y	Y	N	
Office	946	0	76	21	2	Y	Y	Y	
Room 3	756	0	77	18	0	Y	Y	N	
ESL	776	0	73	24	1	Y	N	N	
H S	1108	0	75	23	20	Y	N	N	Door open Carpet behind --?
Teachers Lounge	796	0	77	20	4	N	N	N	Paneling, carpet Coke cans
Resource	522	0	76	16	1	Y	N	N	8 computers

*** ppm = parts per million parts of air**
WB = wall erase board

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	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%